AD-A134 020

(12)

ADF300355

AD

MEMORANDUM REPORT ARBRL-MR-03309

(Supersedes IMR No. 760)

A STRAIN-SONDE TECHNIQUE FOR THE MEASUREMENT OF MECHANICAL TIME-DELAY FUZE FUNCTION TIMES AND PERFORMANCE

Wallace H. Clay

DTIC ELECTE OCT 17 1983 A

September 1983

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

Approved for public release; distribution unlimited.

DTIC FILE COPY

83 10 17 012

Destroy this report when it is no longer needed.
Do not return it to the originator.

Additional copies of this report may be obtained from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

The use of trade names or manufacturers' names in this report does not constitute indorsement of any commercial product.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER MEMORANDUM REPORT ARBRL-MR-03309	2. GOVT ACCESSION NO. AD-A134020	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A STRAIN-SONDE TECHNIQUE FOR THE MEASUREMENT OF MECHANICAL TIME-DELAY FUZE FUNCTION TIMES AND PERFORMANCE		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Wallace H. Clay		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Ballistic Research Laboratory ATTN: DRSMC-BLL(A) Aberdeen Proving Ground, MD 21005		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1L162618AH80
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research & Development Command US Army Ballistic Research Laboratory (DRDAR-BLA-S) Aberdeen Proving Ground, MD 21005		12. REPORT DATE September 1983 13. NUMBER OF PAGES 28
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This report supersedes BRL IMR No. 760 dated December 1982.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

M577 Mechanical Time-Delay Fuze	FM/FM Telemeter
Interlock Pin Release	Semiconductor Strain Gage
Rotor	Signal Condition Amplifier
Firing Pin	In-Flight Measurement
Trigger Assembly-Escapement Mechanism	Clock Pulse

20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (lcb)

A technique has been developed for an in-flight measurement of function time and the clock rate of the M577 mechanical time-delay fuze. A full-bridge, semiconductor strain gage is bonded to the projectile ogive in the vicinity of the fuze well. The output of the strain-gage bridge is conditioned by a high-gain, wide frequency bandwidth amplifier and telemetered to a ground receiving station using an FM/FM telemetry package aboard the projectile.

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Block 20. ABSTRACT (Continued):

The strain-sonde is sensitive enough to respond to the escapement mechanism in the timer of the M577 fuze. The response is in the form of a train of high-frequency pulses from strain-sonde. The repetitive rate of the pulse train corresponds to the "tic-toc" or clock rate of the fuze. The frequency content of each pulse depends upon projectile and fuze configuration; but, generally, frequency components of approximately 1Khz, 4Khz, and up to 8Khz have been measured in conjunction with an M509 projectile. The signal-to-noise ratio of the voltage signal from the strain-sonde varies from 2:1 to 4:1 but is sufficient to obtain an accurate measurement of the M577's clock rate. The strain-sonde also detects other mechanical events or operations associated with the fuze. For example, with the M577 fuze, the arming mechanism is detected, the motion of the rotor in the safe-sensing device is detected, and the operation of the firing pin is detected. The ability to detect all of these events with the fuze strain-sonde allows the complete operational sequence of the fuze to be monitored and measured under real flight conditions. Clock rates, arming times, and function times can be checked. The technique was used in firing tests at the Aberdeen Proving Ground in June 1980 and September 1982.

The strain-sonde technique described here should be adaptable to any mechanical fuze system where event sensing of a mechanical action, such as fuze arming or firing pin action, is required.

TABLE OF CONTENTS

DTIC COPY INSPECTED 2

Accession For
NTIS
A

LIST OF ILLUSTRATIONS

I. INTRODUCTION

A technique for making in-flight measurements of the clock rate of an M577 mechanical time-delay fuze and for the measurement of major event times of the M577 fuze has been developed at the Ballistic Research Laboratory.

The technique consists of using a strain-gage transducer mounted on the fuze or the ogive of the projectile to sense the mechanical motions associated with the escapement mechanism in the fuze timer assembly, safety and arming device (called the safe separation device or SSD), and trigger assembly of the fuze which contains a firing pin and restraining devices. All of the above motions involve the movement of metal parts via escapement mechanisms or of metal parts striking metal parts. They all produce an impulse to the fuze structure and, hence, to the ogive of the projectile containing the fuze. The strain-gage transducer is used to detect the response of the structure upon which it is mounted. The signals produced by the strain-gage are filtered, amplified, and transmitted to a ground receiving station via an FM/FM telemeter on board the projectile.

II. M577 MECHANICAL TIME-DELAY FUZE

There are three basic mechanisms in the M577 fuze which determine its operation. The first is the timer assembly which includes a main spring and an escapement mechanism. The timer assembly is responsible for the basic timed operation of the fuze with the escapement mechanism operating at a rate of 80.7 hertz. The rate of the timer is one of the parameters to be measured in the in-flight tests. The second major assembly of the fuze is the trigger assembly. The trigger assembly contains an arm (called the trigger arm) that rides in a spiral scroll contained in the base of the timer assembly. When the timer is operating, the scroll rotates, causing the trigger arm to move radially outward. The trigger assembly also contains a "catch" that acts as a constraint for an interlock pin between the trigger assembly and the third major component of the fuze, the safe separation device or SSD. The SSD is used as a safe and arming device. It contains a rotor which is an arm with a mass on one end and a detonator cup on the other. In the safe position, the detonator cup is offset from the spin axis of the fuze. Centripetal forces due to the spinning motion of the projectile act on the rotor to rotate the detonator into position along the axis of the fuze end, directly below the firing pin in the base of the trigger assembly. This rotation is prevented from taking place by the interlock pin between the SSD and the trigger assembly. At 3.5 to 4.0 seconds before the preset function time, the interlock pin is released (a major event) and the rotor rotates the detonator into position and locks in place (another major event). This action takes about 0.4 second. At its completion the fuze is armed. The final major event is the release of the firing pin.

The goal of the in-flight measurement, then, is to detect the motion of the escapement mechanism in the timer assembly to obtain clock rates and to detect the times and sequence of occurrence of all the major events mentioned above.

III. STRAIN-GAGE TRANSDUCER AND TELEMETRY SYSTEM

The technique developed to make in-flight measurements on the M577 fuze is to mount a strain-gage transducer somewhere on the fuze or projectile ogive and to amplify the strain-gage signals with a high-gain, wide-bandwidth amplifier. The amplifier output signals are transmitted to a ground receiving station via a standard FM/FM telemeter.

The gage chosen was a high gage factor (g.f. = 155) semiconductor strain-gage mounted on a 1/4-inch by 3/8-inch substrate. The gage elements are in a full-bridge configuration, chosen to provide maximum signals from the structural response of ogive/fuze to the fuze mechanisms. Flight tests have been made with the strain-gage mounted in two different locations. Tests conducted in 1980 had the strain-gage patch mounted on the inside of the windshield of the fuze. This had the advantage of being relatively close to the mechanisms but also had the disadvantage that the fuze had to be modified to make the measurements. A more recent test conducted in August and September of 1982 had the strain-gage mounted on the inside of the ogive of the M509 8-inch projectile. Thus, production lot fuzes could be used without modification. Unfortunately, the gage was more remote to the fuze mechanisms that were to be detected. Results from both of these configurations will be presented later.

Figure 1 shows a schematic of the amplifier circuit used on all tests to condition the strain-gage outputs. The circuit consists of a multistage amplifier with a gain from 13,000 to 15,000 and a response flat from 1,000 hz to greater than 25 kilohertz. The high gain was needed to detect the response to the clock escapement mechanism. Likewise, the wide frequency bandwidth was needed because of the impulsive nature of the various mechanisms being detected. The signals from the strain-gage bridge are high-pass filtered at about 1,000 hertz in order to prevent the amplifier circuit from being overwhelmed by the response strain-gage to aerodynamic forces acting on the projectile. These responses occur at the spin-rate of the projectile (100-200 hz) and from past experience saturate the high gain amplifiers. A subcarrier-oscillator operating at 240 kilohertz and a transmitter operating at a frequency of 1,520 megahertz was used to telemeter the strain-gage signals. The frequency bandwidth of the subcarrier oscillator is greater than 10 kilohertz. Figure 2 shows a block diagram of the telemeter circuit. A yawsonde channel was included in all flight tests.

IV. TEST RESULTS

Preliminary tests of the measurement technique were made in the laboratory using an M577 fuze mounted on a fixture in a gyroscope. The gyroscope was made to spin at rates in excess of 30 rps in order to start the fuze operation. The fuzes were modified to defeat the set-back force mechanisms. The gyroscope package included a telemeter to transmit data to a remote receiving station. Figures 3-5 show some waveforms obtained by this technique with the gyroscope. Figure 3 is a plot of the response of the system to the clock escapement mechanism in the timer assembly. The signal-to-noise ratio (clock pulse amplitude to base-line noise) is about 3:1 which is sufficient to make a determination of clock rate. Figure 4 illustrates the response to the release of the interlock pin which occurs at the initiation of fuze arming.

Note the pulses produced by the escapement mechanism in the SSD device indicating that the rotor is moving the detonator cup into position. Figure 5 shows the impulse produced by the rotor locking into position. Figure 6 shows the response to the release of the firing pin. The fuze did not contain a live detonator for these tests. The results of the gyroscope tests showed that the technique could be used to characterize the behavior of the M577 fuze. Indeed, the measurement technique produced a recognizable signature of events occurring during the operation cycle of the fuze.

Flight tests were made with the M577 fuze on an M509 8-inch projectile in June 1980[1] and again in August-September 1982. The major differences between the two series of tests was the location of the strain-gage. In the 1980 tests the strain-gage was mounted on the inside of the windshield of the M577 fuze. In the 1982 tests the strain-gage was mounted on the inside of the ogive of the M509 projectile and production lot fuzes were used. Figure 7 shows some typical clock pulses obtained for Round BRL-1709 fired in the 1980 tests. This plot shows a signal-noise-ratio of about 4:1 making the determination of clock rate quite easy. (The clock rate was determined by making time interval measurements between clock pulses.) Figures 8 and 9 show the pulses produced by the rotor start and stop motions in the SSD. Notice that the motion of the escapement mechanism is evident from the higher amplitude pulses between rotor start (Figure 8) and rotor lock (Figure 9). Figure 10 shows a pulse occurring at the set function time due to the release of the firing pin. Compare Figures 8 and 9 with Figures 11 and 12. Figure 11 is a plot of the pulse produced by the interlock pin release at about 4.0 seconds before function time (for Round BRL-1710). Notice that the rotor in the SSD device started to move and then stopped. Figure 12 shows a pulse occurring at the function time set for this round (BRL-1710). The time of occurrence of this pulse and the nature of the pulse itself indicates that it is produ ' by the release of the firing pin. These rounds did not have live detonators. Periodic pulses occur after the firing pin pulse shown in Figure 12. These pulses are produced by the motion of the rotor in the SSD. The results indicate that the fuze for Round BRL-1709 functioned correctly in all respects. The times of occurrences of all the events were correct. However, while the times of occurrences of the interlock pin release and the firing pin release were correct for Round BRL-1710, the fuze did not arm itself correctly. That is, the rotor started but then stopped for some reason and did not continue until it was jarred loose by the release of the firing pin. Figure 13 shows a large pulse that occurs after the firing pin releases and probably results from the detonator cup striking the firing pin. This fuze would probably have been a dud with a live detonator.

The results obtained from the more recent tests in 1982 are shown in Figures 14-16. Figure 14 shows both the interlock pin release pulse (rotor start) and the rotor lock pulse for Round BRL-1788. The times of occurrence of these pulses are correct as is the time for the firing pin pulse shown in Figure 15. The fuzes used in the 1982 tests had live detonators. Detonator

---

1. *Wallace H. Clay and James B. Harmon, "Telemetry Test Results With the M509/M577 Projectile/Fuze System," Ballistic Research Laboratory Memorandum Report ARBRL-MR-03187, July 1982 (AD B065740).*

functions are seen in the durations of the firing pin pulses at the set function time. The duration of the pulse resulting from the release of the firing pin and subsequent functioning of the detonator is about 100 milliseconds compared to 10-20 milliseconds resulting from the release of the firing pin alone. (See Figure 10.) These data are typical for the recent tests fired in 1982. All of the fuzes functioned properly in this test series. A plot of some typical clock pulses produced by the timer mechanism is shown in Figure 16. It is clear that the response of the measurement system to the escapement mechanism in the timer assembly is worse in the second series than in the earlier series. This is due in part to the fact that the strain-gage patch is located further from the fuze assembly. It is also the result of the fact that production lot fuzes were used in the 1982 tests. The production lot fuzes have a silicone type sealant applied to the threads of the windshield of the fuze which further isolates the fuze from the strain-gage.

V. CONCLUSION

The results obtained in two series of tests show that the strain-gage technique described in this paper can be successfully used to characterize and determine the behavior of the M577 time delay fuze in-flight. The detection of timed events can be made even with the strain-gage located on the ogive of the projectile being tested. Further work is needed to improve the signal-noise-ratio of the pulses produced by the clock mechanism for the case where the strain-gage is located on the ogive and not on the fuze itself.

It should be clear that the technique described in this paper can be applied to systems other than the M577 fuze. Indeed, it can be used and adapted to any system or fuze which involves the detection of the motion of mechanical parts.

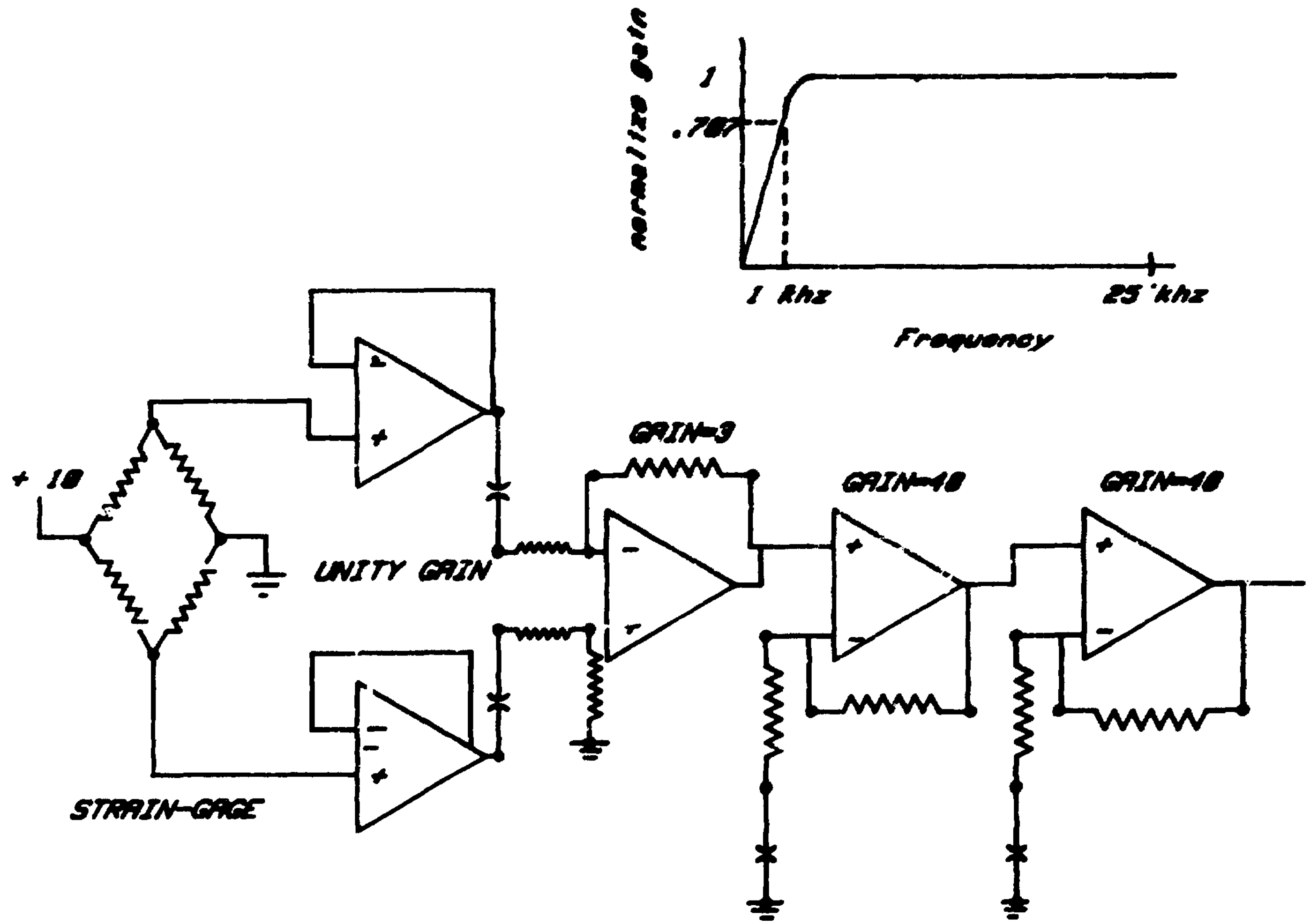

Figure 1. Strain-Gage Amplifier Circuit

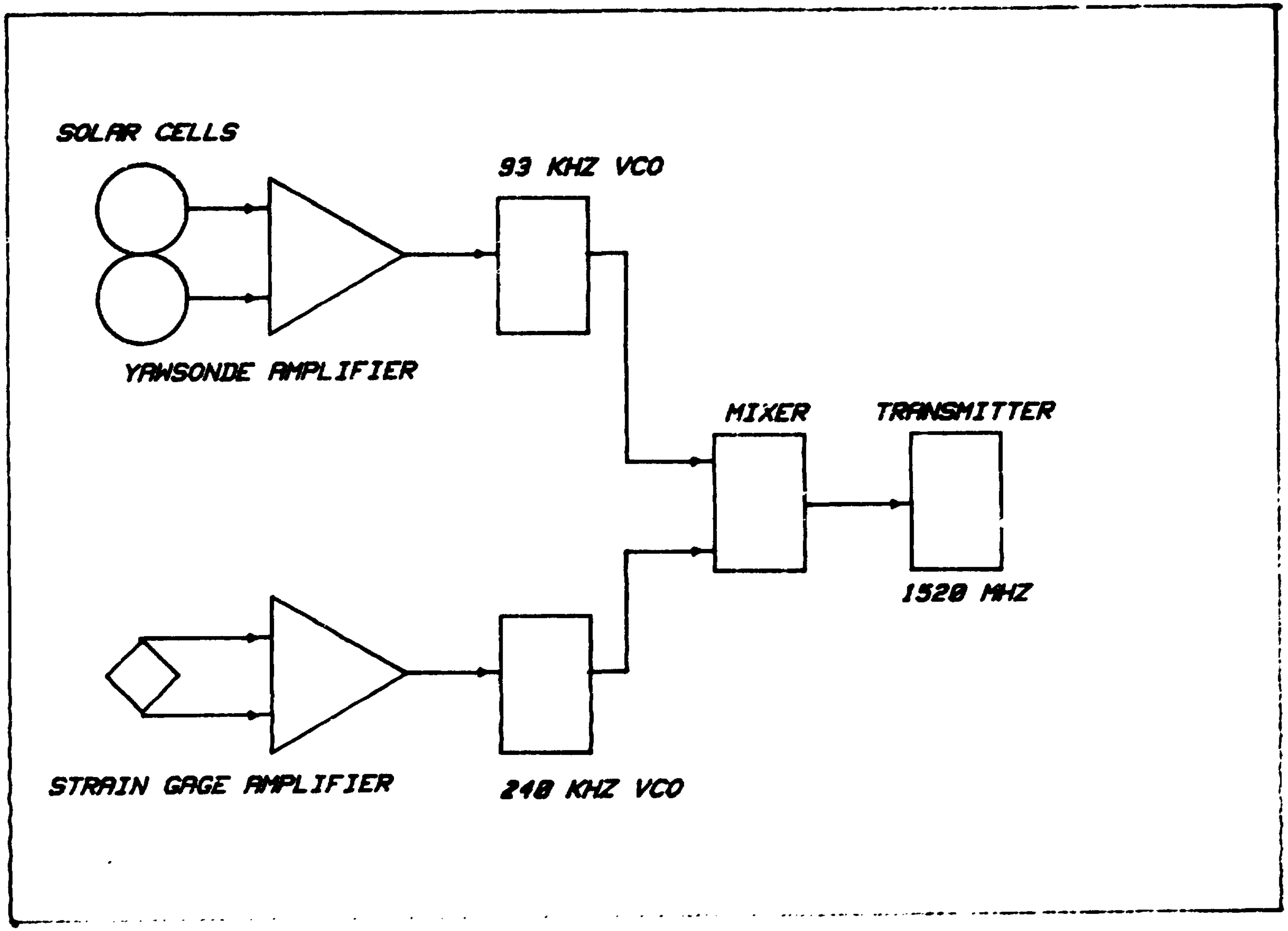

Figure 2. Schematic of the Telemeter Circuit

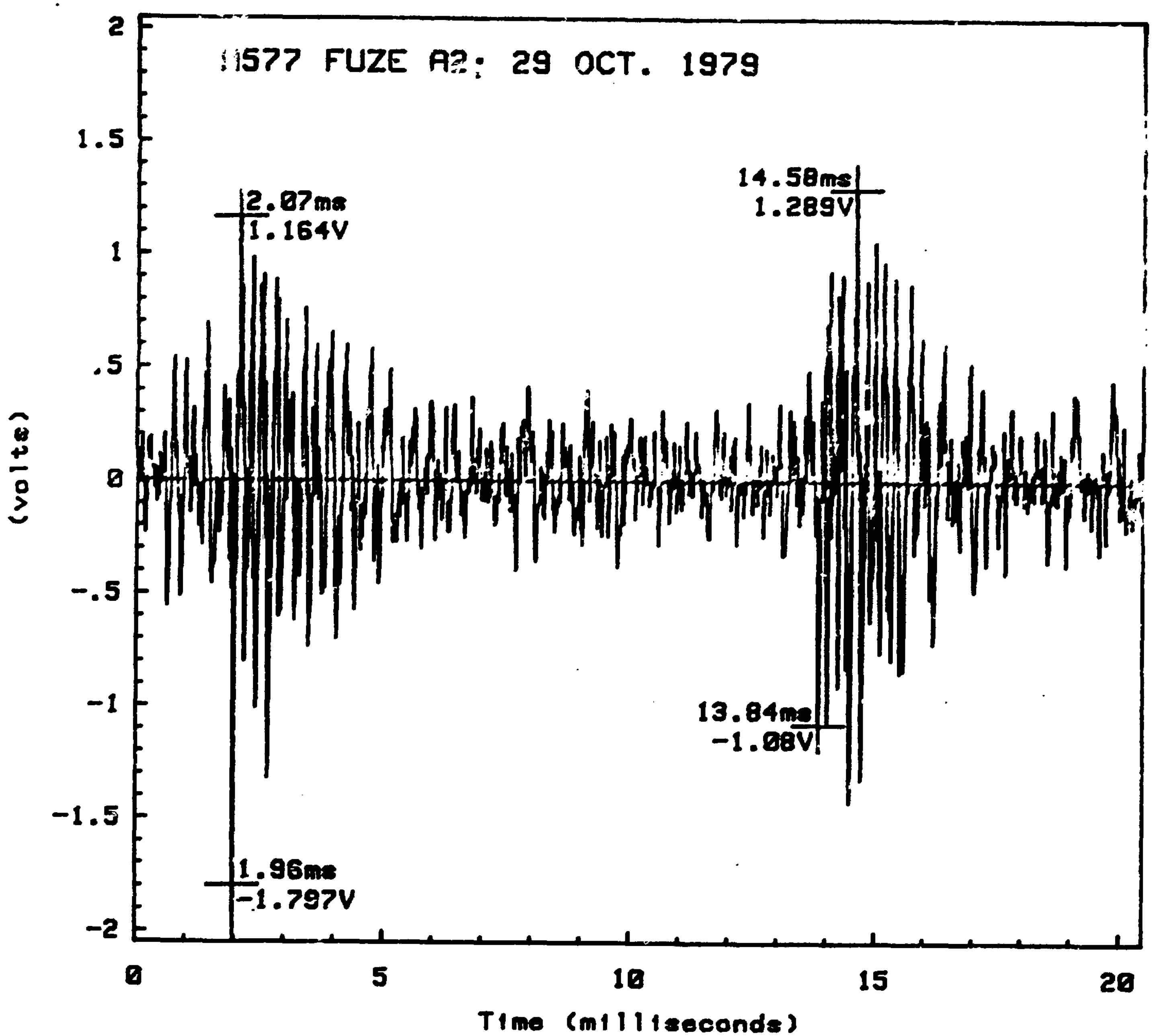

Figure 3. Strain-Gage Signals in Response to Timer Clock Mechanisms (Gyroscope Data)

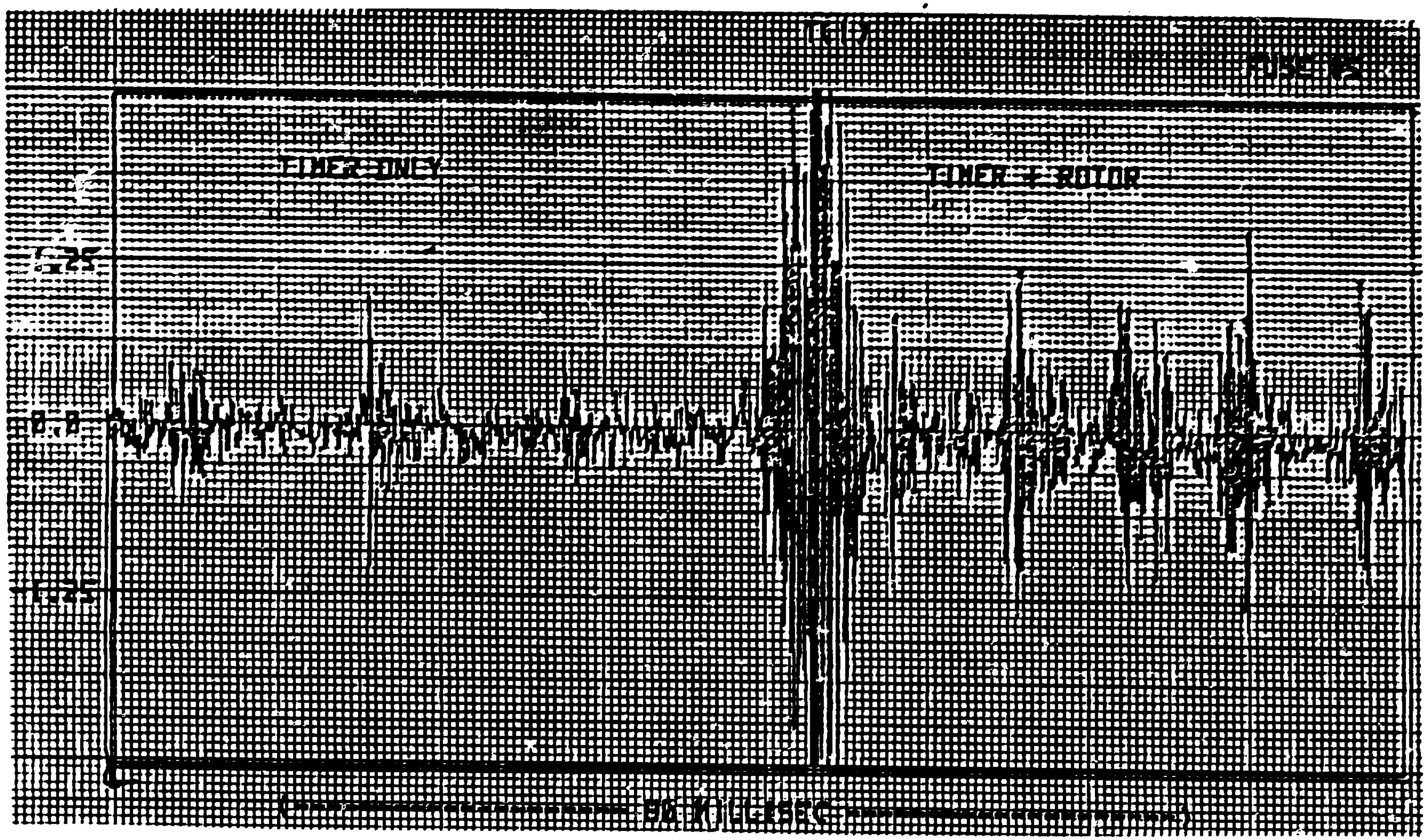

Figure 4. Strain-Gage Signal in Response to Interlock Pin Release and to Rotor Mechanism (Gyroscope Data)

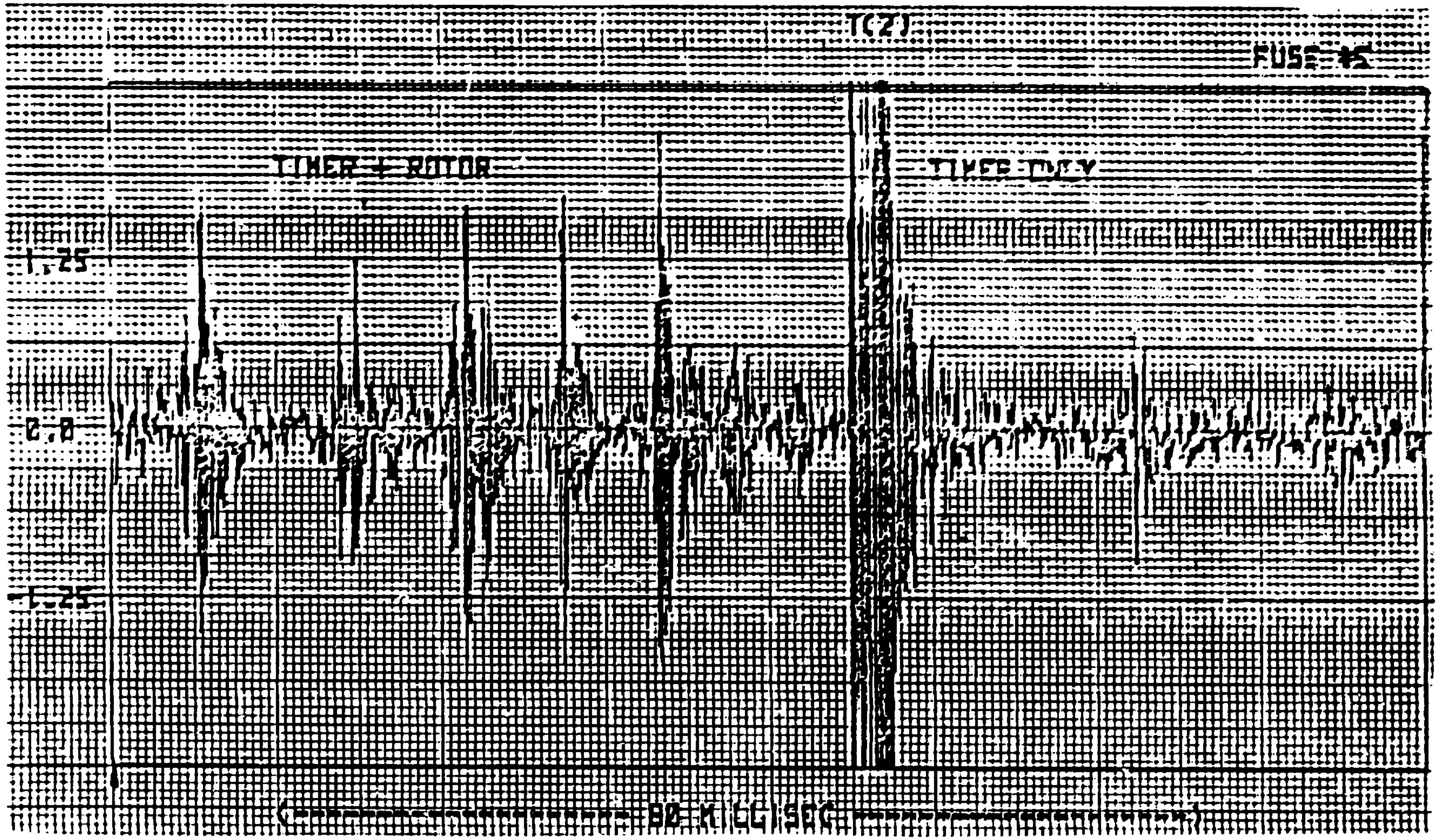

Figure 5. Strain-Gage Signal in Response to Rotor Motion and Rotor Lock Mechanism (Gyroscope Data)

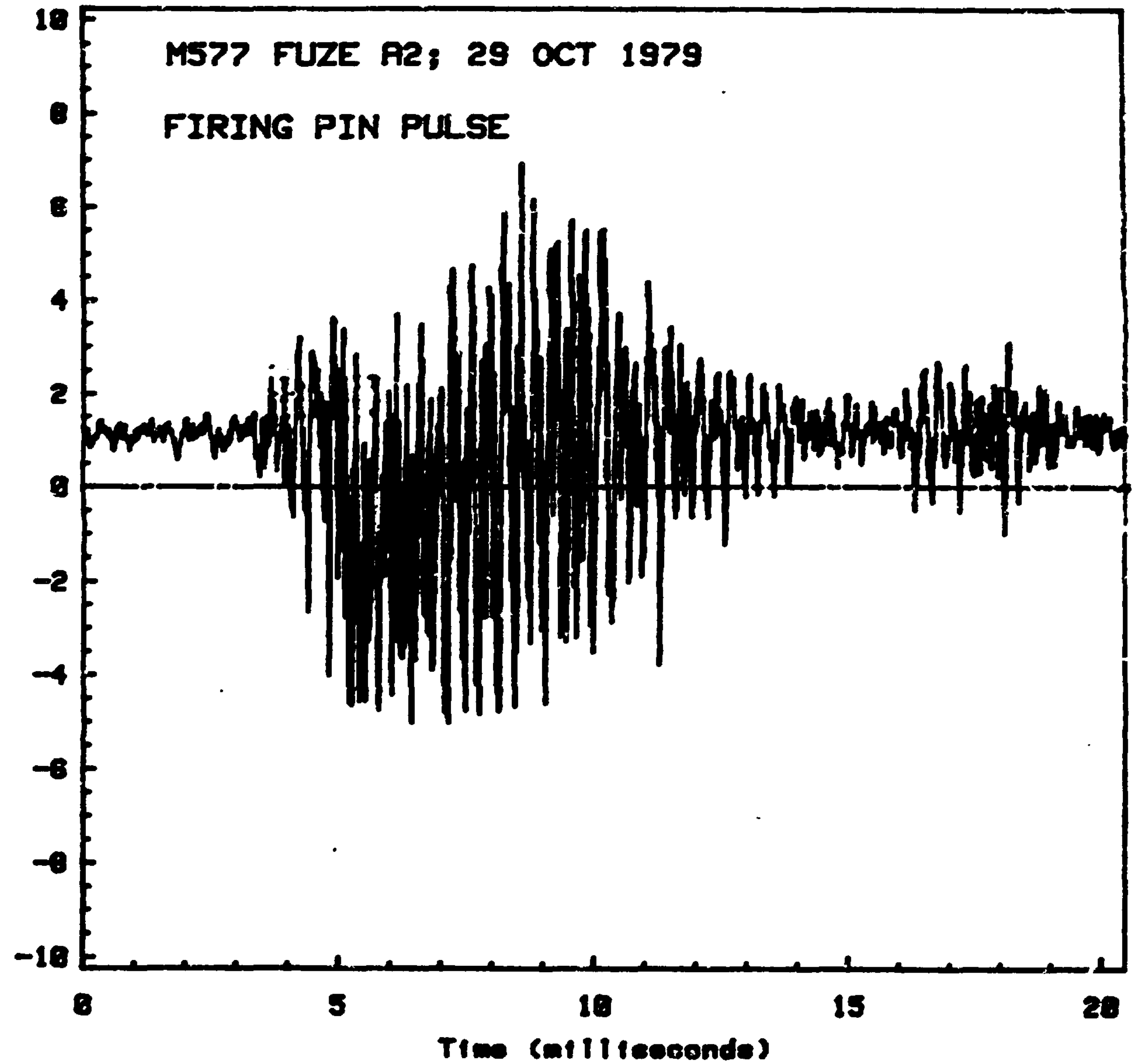

Figure 6. Strain-Gage Signal in Response to Release of Firing Pin Mechanism (Gyroscope Data)

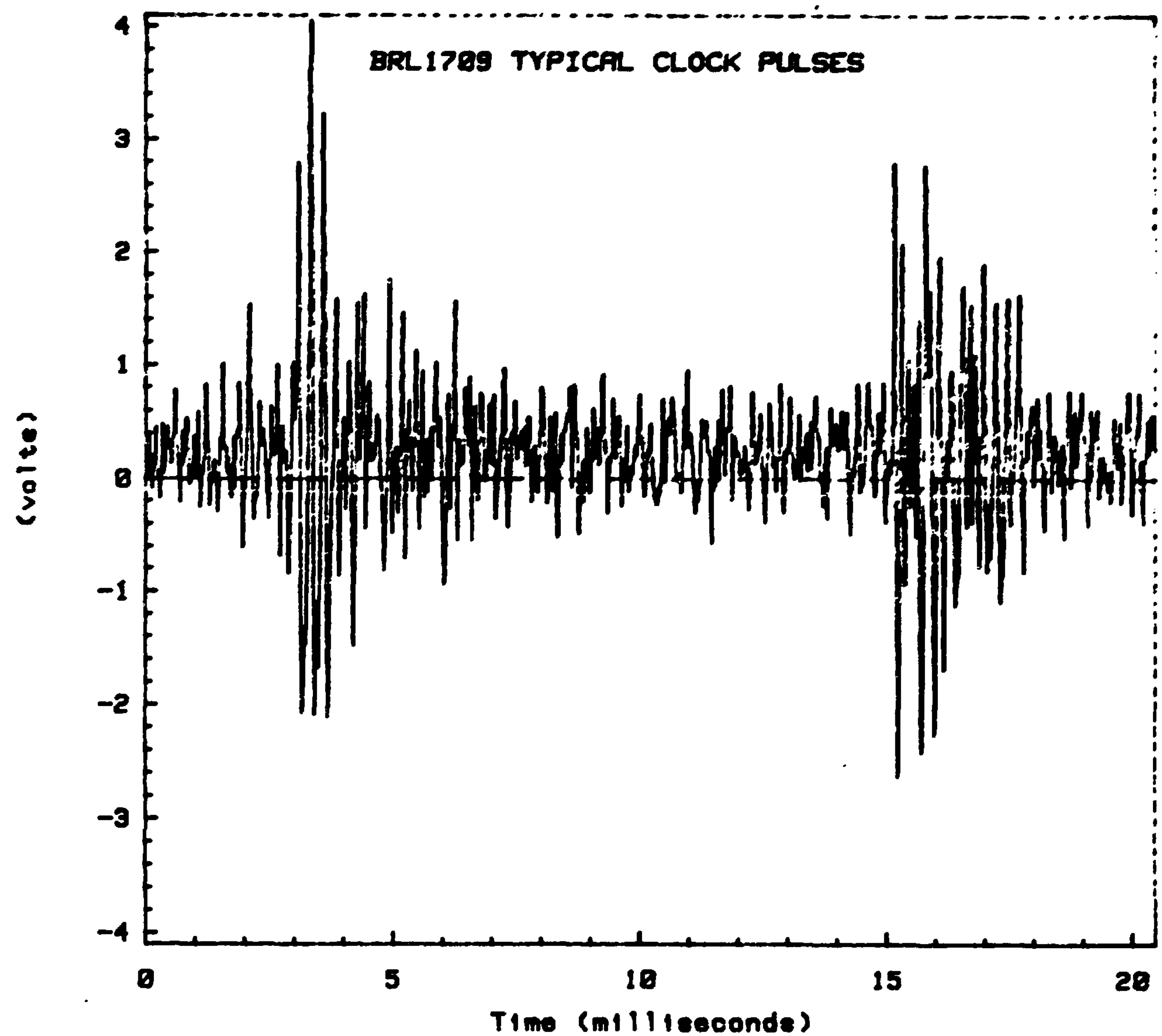

Figure 7. Typical Timer Clock Pulses for BRL 1709 (June 1980)

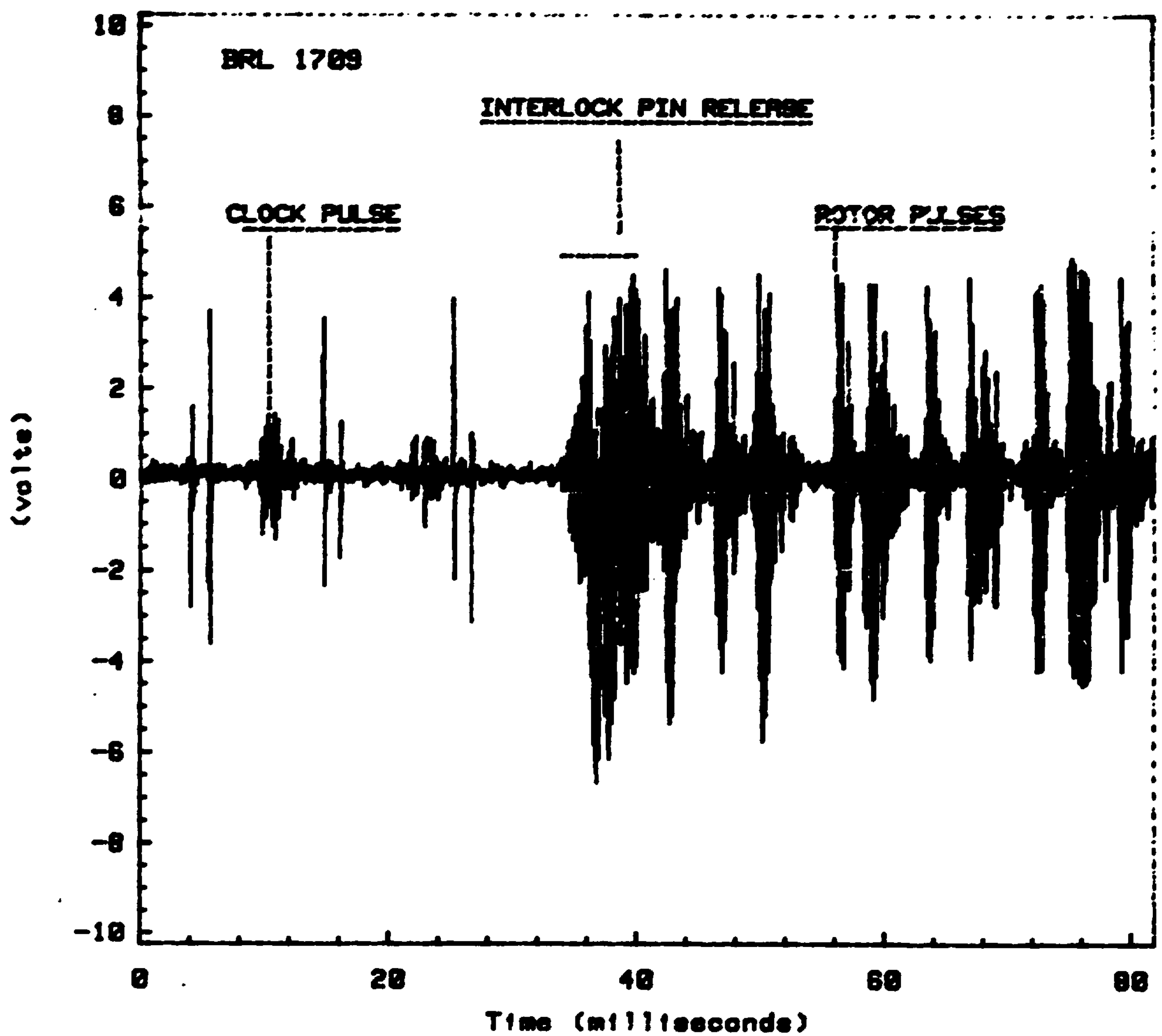

Figure 8. Interlock Pin Release Pulse and Rotor Pulses for BRL 1709 (0 time = T_0 + 50.95 seconds) (June 1980)

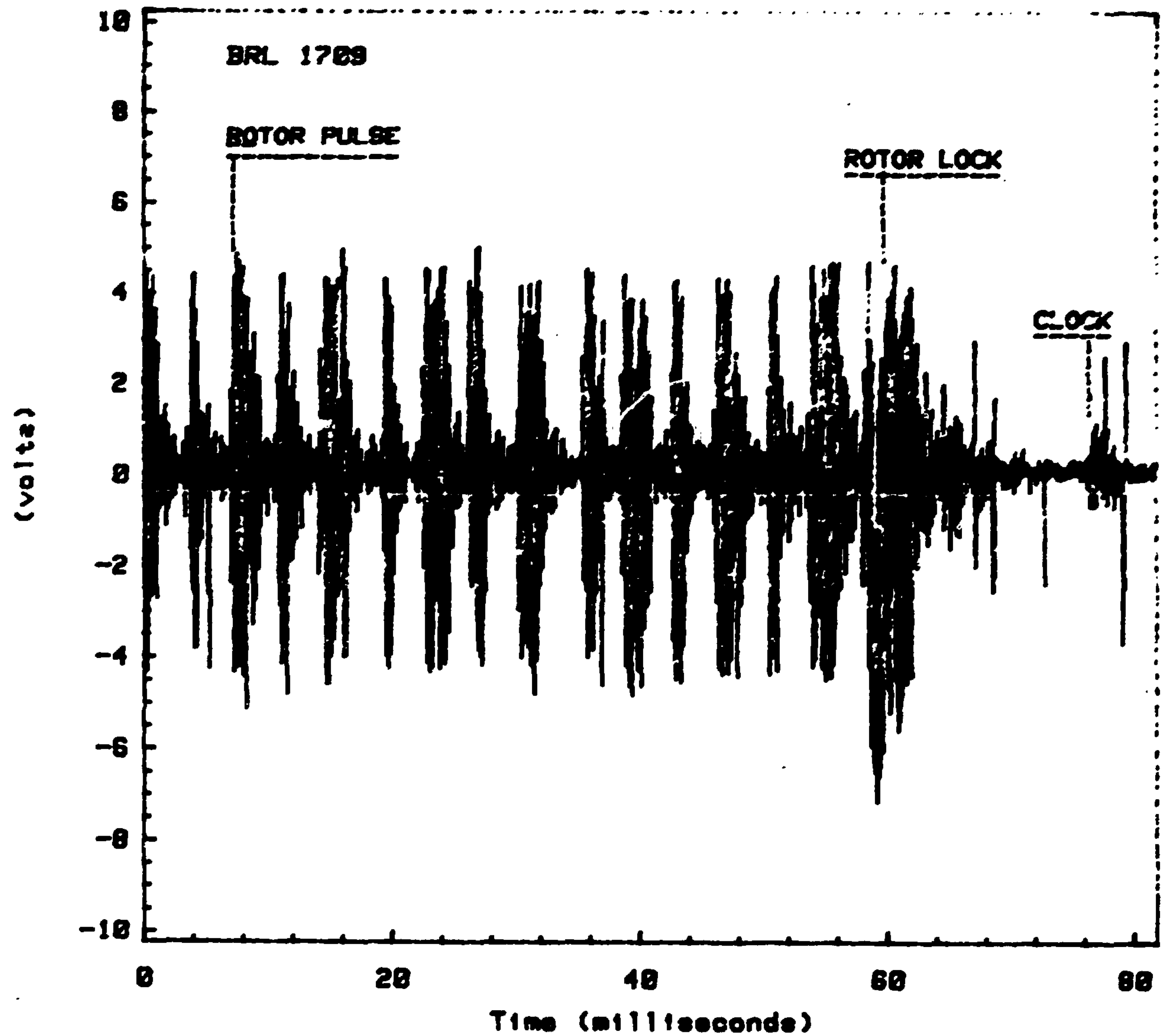

Figure 9. Rotor Pulses and Rotor Lock Pulse for BRL 1709 (0 time = T_0 + 51.33 seconds) (June 1980)

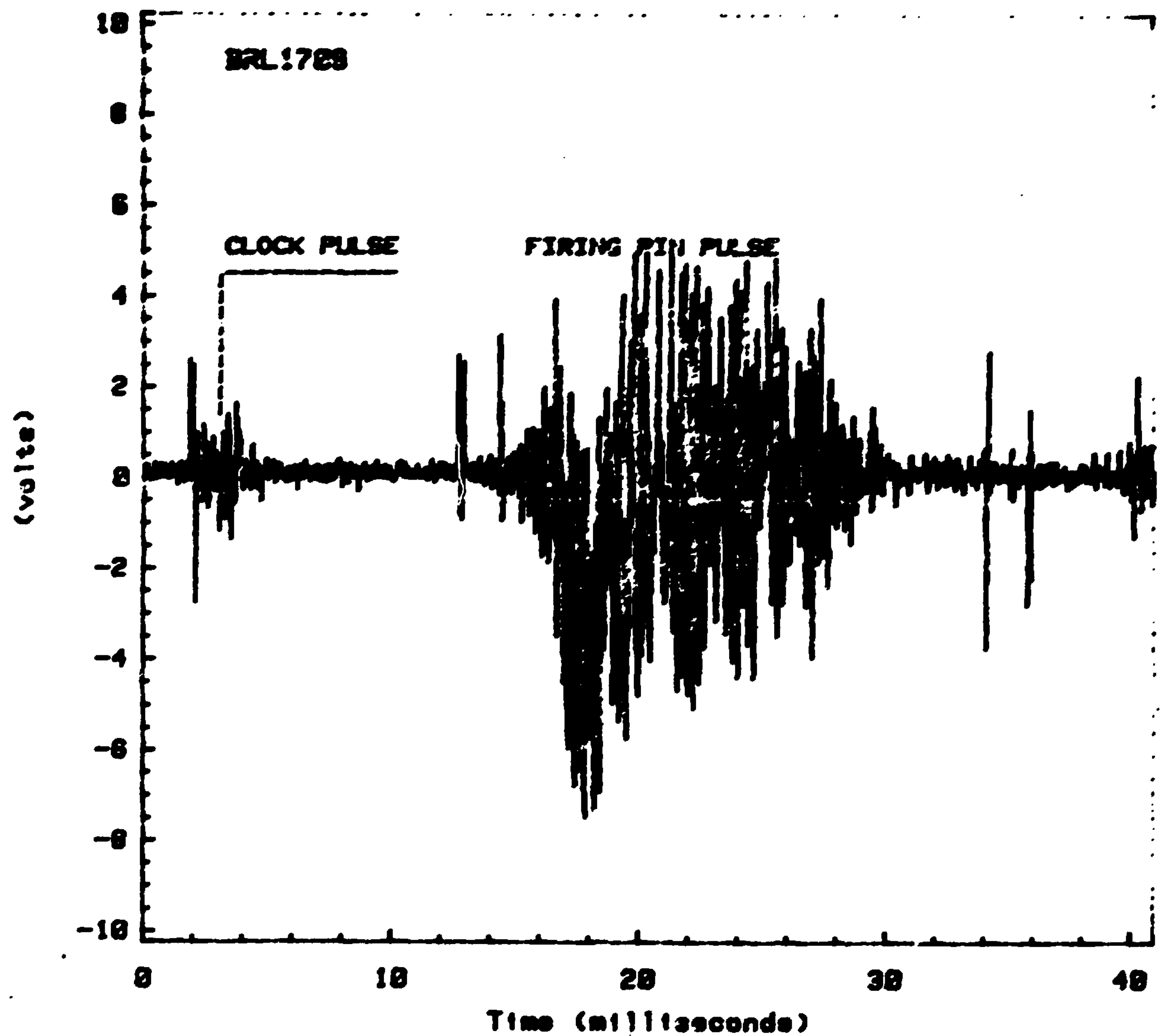

Figure 10. Firing Pin Pulse for BRL 1709 (0 time = T_0 + 55.08 seconds) (June 1980)

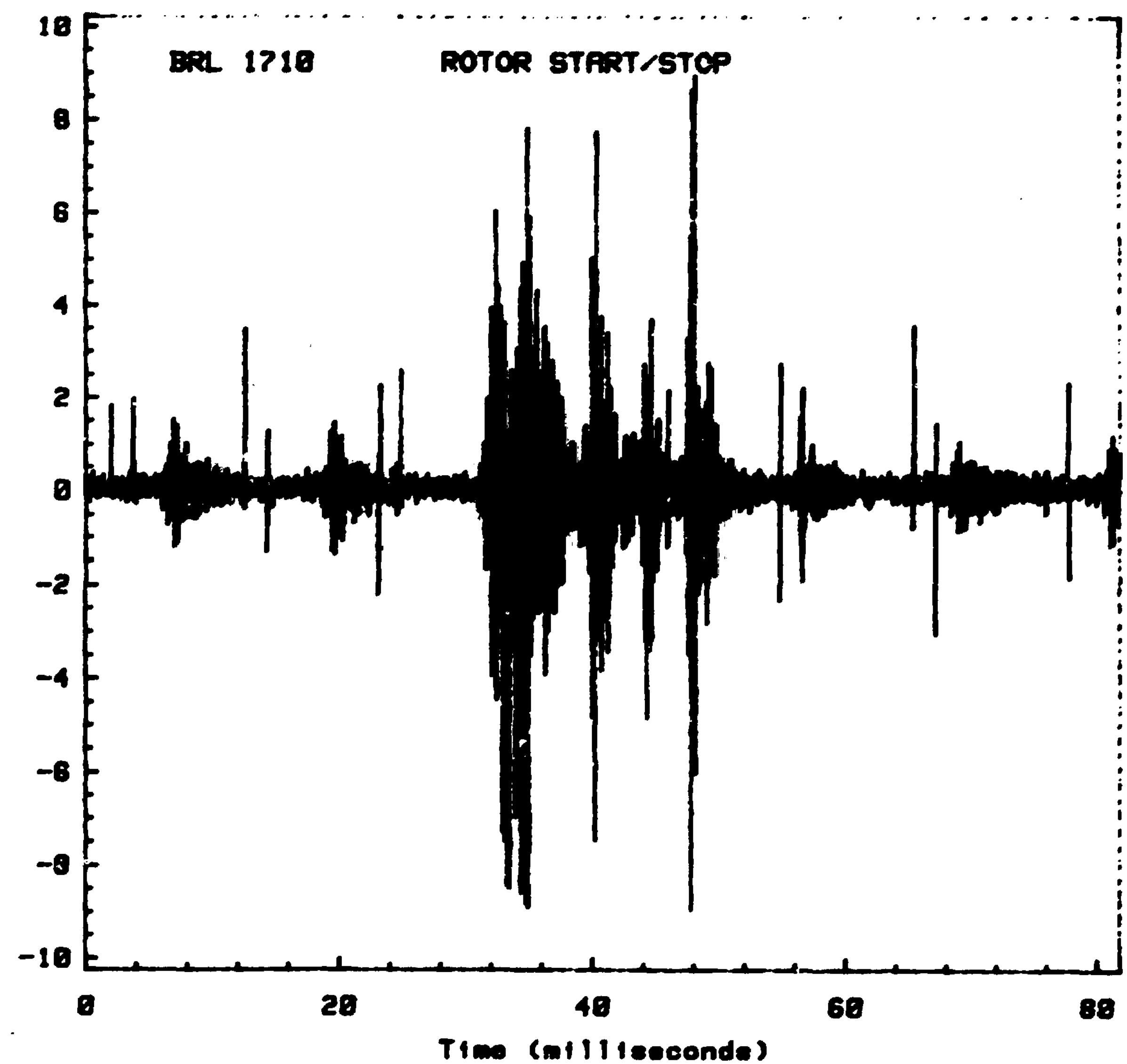

Figure 11. Interlock Pin Release Pulse and a Few Rotor Pulses for BRL 1710 (0 time = T_0 + 50.670 seconds) (Note Start/Stop of Rotor)

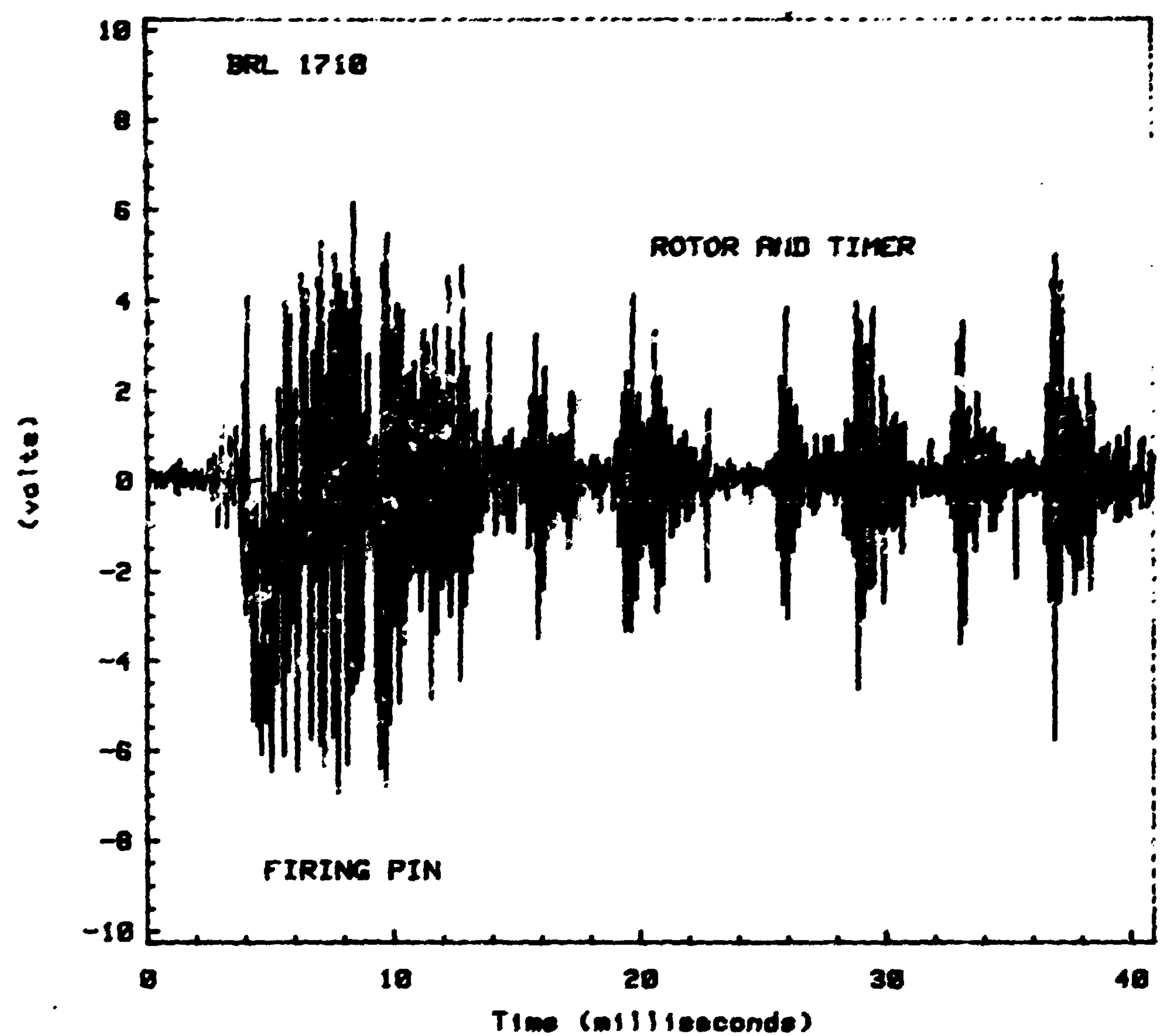

Figure 12. Firing Pin Pulse Followed by Rotor Pulses for BRL 1710 (0 time = T_o + 54.917 seconds) (June 1980)

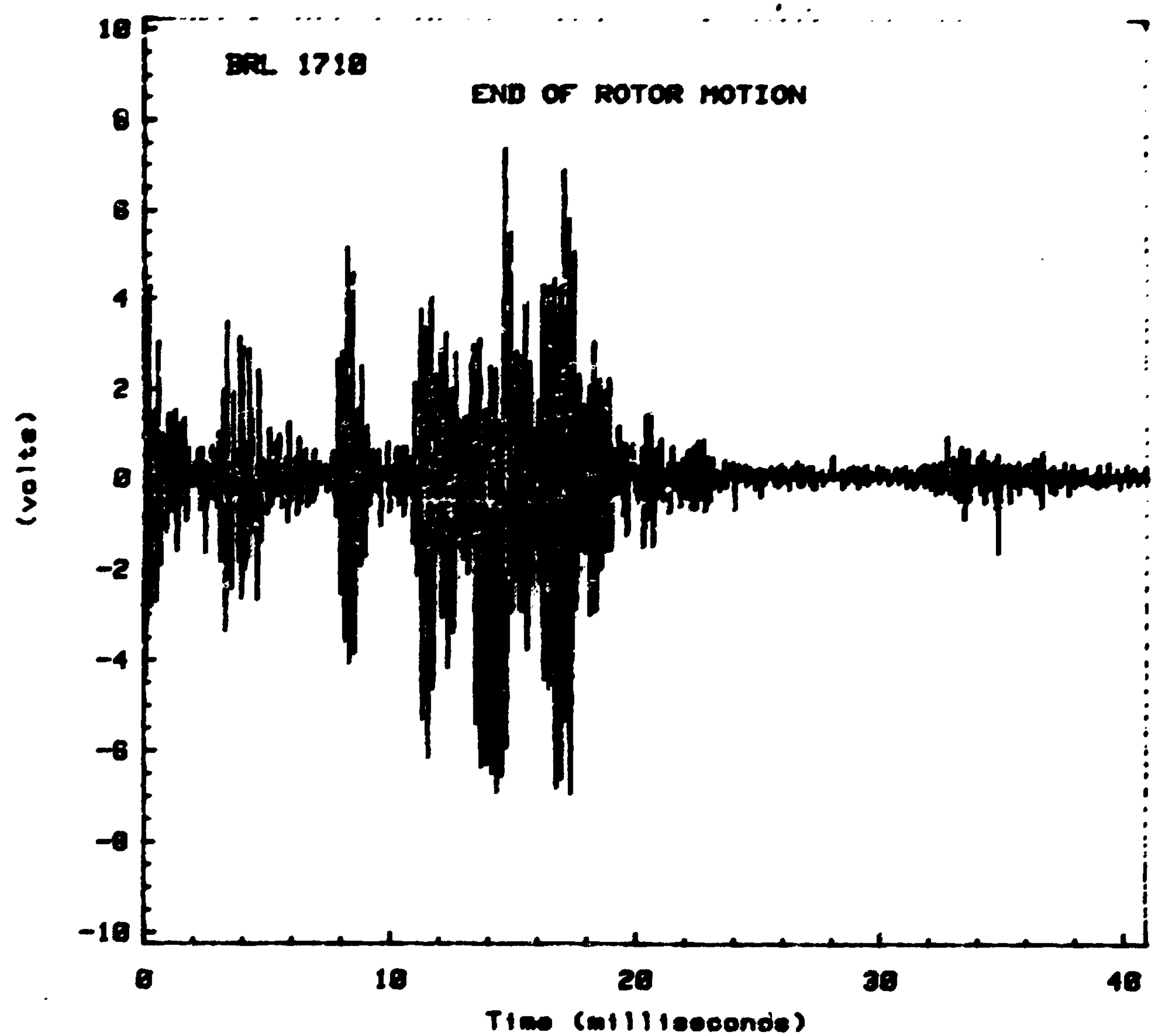

Figure 13. Rotor Stop Pulse for BRL 1710 (0 time = T_0 + 55.332 seconds)
(Rotor stop occurs after release of firing pin) (June 1980)

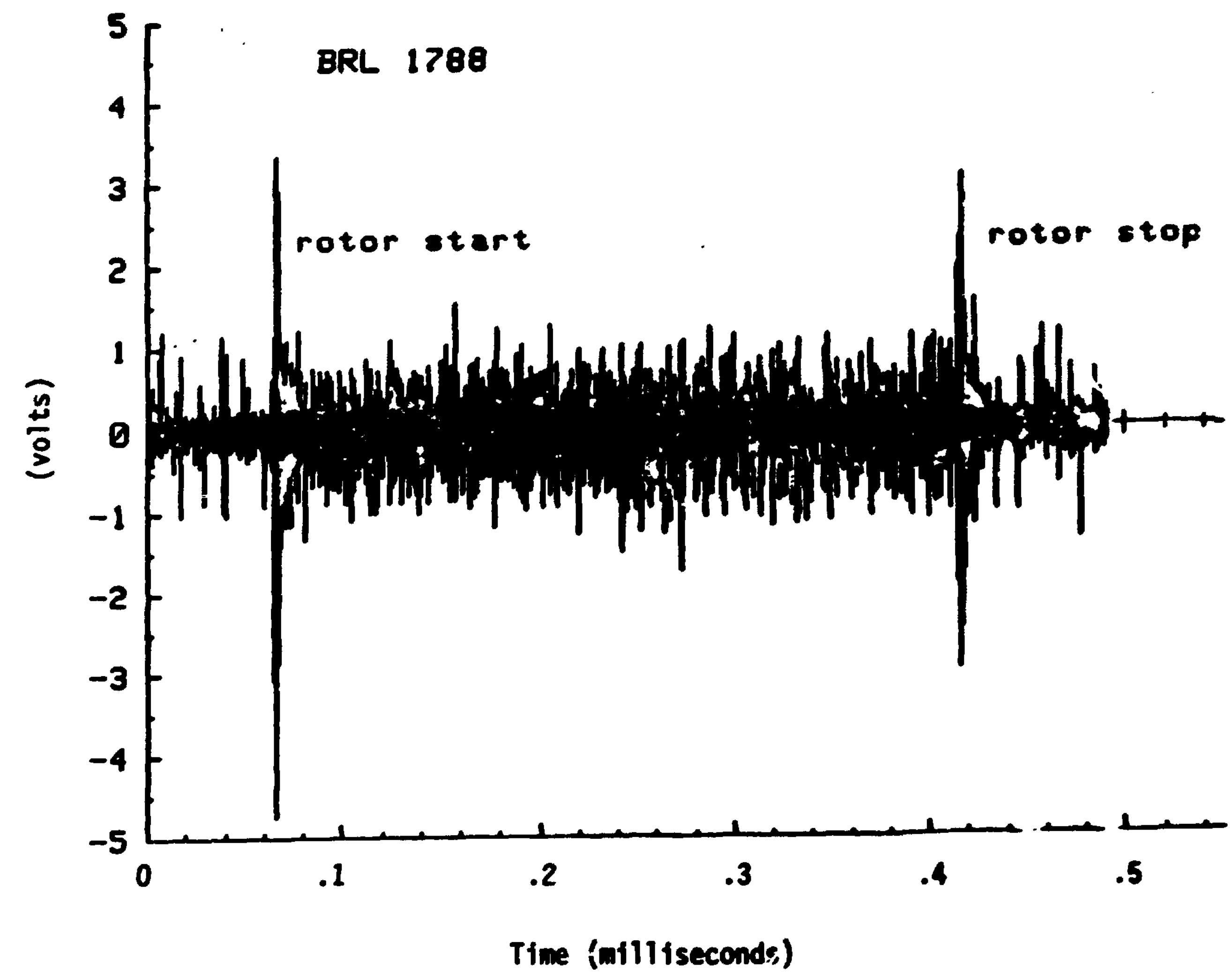

Figure 14. Interlock Pin Release Pulse (Rotor Start) and Rotor Lock Pulse for BRL 1788 (September 1982) (0 time = T_0 + 39.93 seconds)

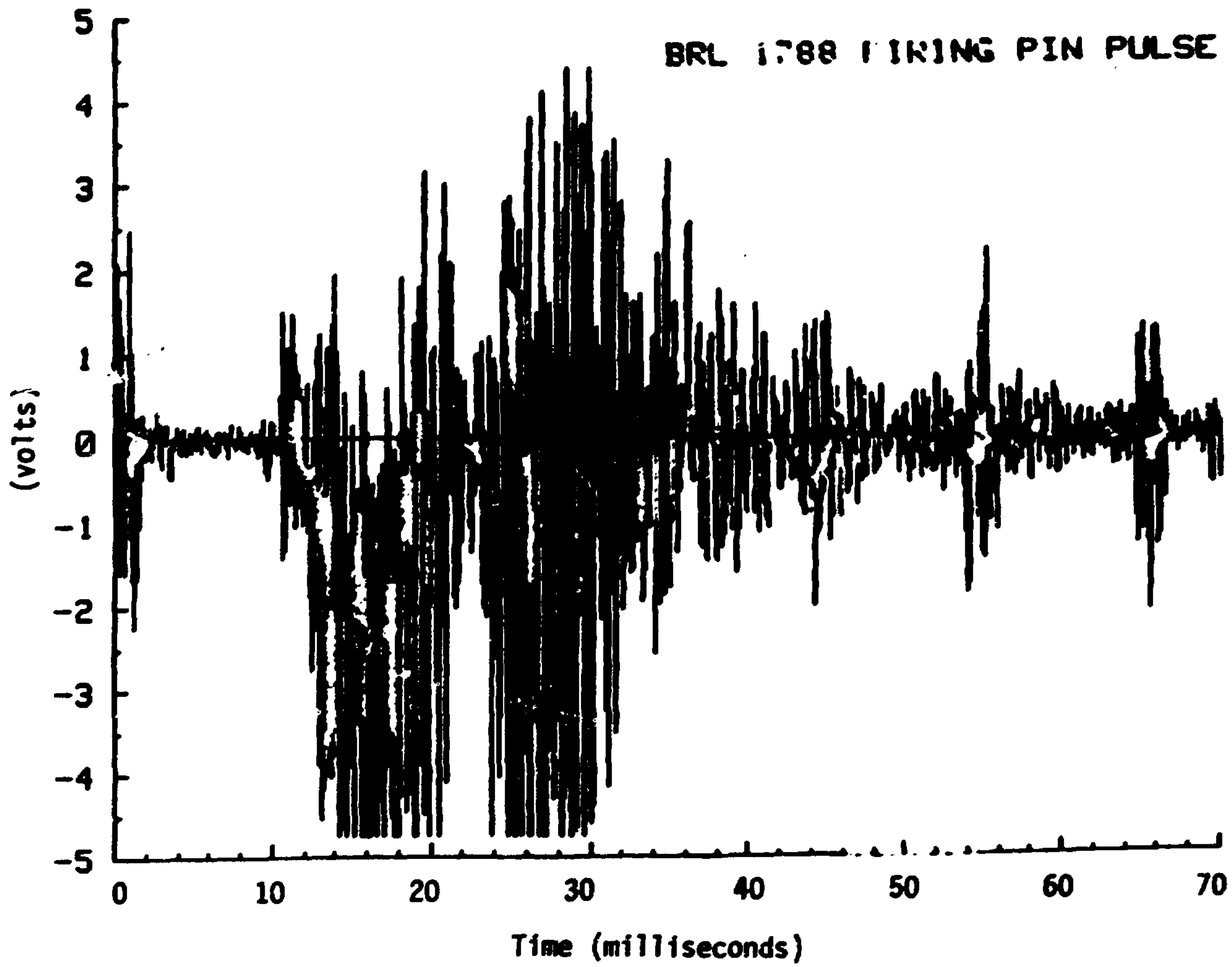

Figure 15. Firing Pin and Detonator Function Pulse for BRL 1788 (September 1982) (0 time = T_o + 39.93 seconds)

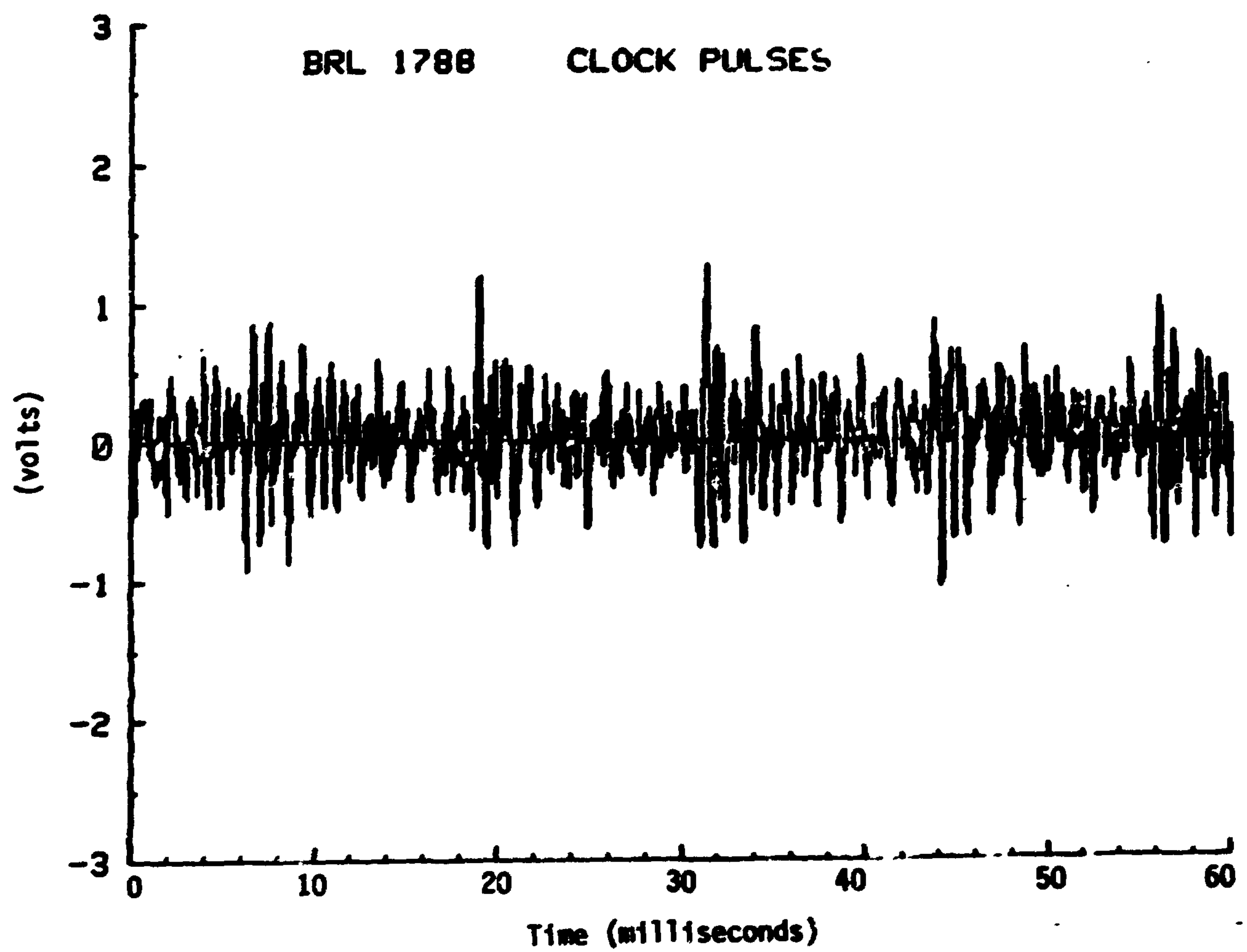

Figure 16. Typical Timer Clock Pulses for BRL 1710 (September 1982)

DISTRIBUTION LIST

No. of Copies	Organization
12	Administrator Defense Technical Information Center ATTN: DTIC-DDA Cameron Station Alexandria, VA 22314
1	Commander US Army Materiel Development and Readiness Command ATTN: DRCDMD-ST 5001 Eisenhower Avenue Alexandria, VA 22333
1	Commander Armament Research and Development Center US Army Armament, Munitions and Chemical Command ATTN: DRSMC-TDC(D) Dover, NJ 07801
2	Commander Armament Research and Development Center US Army Armament, Munitions and Chemical Command ATTN: DRSMC-TSS(D) Dover, NJ 07801
1	Commander Armament Research and Development Center US Army Armament, Munitions and Chemical Command ATTN: DRSMC-LCA-F(D) Mr. A. Loeb Dover, NJ 07801
1	Commander Armament Research and Development Center US Army Armament, Munitions and Chemical Command ATTN: DRSMC-LC(D) Dr. J. T. Frasier Dover, NJ 07801
3	Commander Armament Research and Development Center US Army Armament, Munitions and Chemical Command ATTN DRSMC-LCN(D) Mr. F. Saxe Mr. D. Taravella (2 cys) Dover, NJ 07801
2	Commander Armament Research and Development Center US Army Armament, Munitions and Chemical Command ATTN: DRSMC-TSD(D) Mr. R. Geaney Mr. L. H. Glass Dover, NJ 07801
1	Commander US Army Armament, Munitions and Chemical Command ATTN: DRSMC-LEP-L(R) Rock Island, IL 61299
1	Commander ARDC, USA AMCCOM Benet Weapons Laboratory ATTN: DRSMC-LCB-TL Watervliet, NY 12189
1	Commander US Army Aviation Research and Development Command ATTN: DRDAV-E 4300 Goodfellow Blvd St. Louis, MO 63120
1	Director US Army Air Mobility Research and Development Laboratory Ames Research Center Moffett Field, CA 94035

DISTRIBUTION LIST

No. of Copies	Organization
1	Commander US Army Communications Research and Development Command ATTN: DRSEL-ATDD Fort Monmouth, NJ 07703
1	Commander US Army Electronics Research and Development Command Technical Support Activity ATTN: DELSD-L Fort Monmouth, NJ 07703
1	Commander US Army Missile Command ATTN: DRSMI-R Redstone Arsenal, AL 35898
1	Commander US Army Missile Command ATTN: DRSMI-YDL Redstone Arsenal, AL 35898
1	Commander US Army Tank Automotive Command ATTN: DRSTA-TSL Warren, MI 48090
1	Director US Army TRADOC Systems Analysis Activity ATTN: ATAA-SL White Sands Missile Range NM 88002
2	Commandant US Army Infantry School ATTN: ATSH-CD-CSO-OR Fort Benning, GA 31905
1	AFWL/SUL Kirtland AFB, NM 87117
1	Commander US Army Harry Diamond Laboratories ATTN: DELHD-TA-L 2800 Powder Mill Road Adelphi, MD 20783
1	Bulova System and Instruments Corporation ATTN: Mr. Roy Nystrom Green Acres Road, West Valley Stream, NY 11582

Aberdeen Proving Ground

Director, USAMSAA
ATTN: DRXSY-D
DRXSY-MP, Mr. H. Cohen

Commander, USATECOM
ATTN: DRSTE-TO-F

PM-SMOKE, APG-AA
ATTN: DRCPM-SMK

Commander, USACRDC
Bldg. E3516, APG-EA
ATTN: DRSMC-CLB-PA
DRSMC-CLN
Mr. W. Dee
Mr. C. Hughes
DRSMC-CLJ-L

USER EVALUATION OF REPORT

Please take a few minutes to answer the questions below; tear out this sheet, fold as indicated, staple or tape closed, and place in the mail. Your comments will provide us with information for improving future reports.

1. BRL Report Number ______________________________

2. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which report will be used.)

____

____

____

3. How, specifically, is the report being used? (Information source, design data or procedure, management procedure, source of ideas, etc.) ______________________________

____

____

4. Has the information in this report led to any quantitative savings as far as man-hours/contract dollars saved, operating costs avoided, efficiencies achieved, etc.? If so, please elaborate.

____

____

5. General Comments (Indicate what you think should be changed to make this report and future reports of this type more responsive to your needs, more usable, improve readability, etc.) __________

____

____

____

6. If you would like to be contacted by the personnel who prepared this report to raise specific questions or discuss the topic, please fill in the following information.

Name: ______________________________

Telephone Number: ______________________________

Organization Address: ______________________________

____

____